

Cutting Tool Materials

To effectively select tools for machining, a machinist or engineer must have specific information about:

- the starting and finished part shape
- the workpiece hardness
- the material's tensile strength
- the material's abrasiveness
- the type of chip generated
- the work holding setup
- the power and speed capacity of the machine tool

Changes in any of these conditions may require a thorough review of any cutting tool selection.

Cutting Tool Materials

Different machining applications require different cutting tool materials. The ideal cutting tool material should have all of the following characteristics:

- harder than the work it is cutting
- high temperature stability (HTS)
- resists wear and thermal shock
- impact resistant (fracture toughness)
- chemically inert to the work material and cutting fluid
- suitable coefficient of thermal conductivity, volume specific heat
- grindability

Cutting Tool Materials

No single cutting tool material incorporates all these qualities. Instead, trade-offs occur among the various tool materials.

Every new and evolving tool development has an application where it will provide superior performance over others. Many newer cutting tool materials tend to reduce, but not eliminate the applications of older cutting tool materials.

High Carbon Steel

This material is one of the earliest cutting materials used in machining. It is however now virtually superseded by other materials used in engineering because it starts to temper at about 220 degree C . This softening process continues as the temperature rises. As a result cutting using this material for tools is limited to speeds up to 10 m/min for machining mild steel with lots of coolant. It is used in making cutters, twist drills, turning and form tools for machining soft and free cutting materials like wood, magnesium, brass, aluminium. Also used in hand tools like taps, files, reamers, hacksaw blades etc.

Medium Alloy Steel

The carbon content is 0.6~1.5% with small quantities of silicon, chromium, manganese, and vanadium to refine grain size. Maximum hardness is about HRC 62. This material has low wear resistance and low hot hardness. This is an improvement over HC Steel tool material.

the small scale industries cannot afford costlier tools

the old or low powered small machine tools cannot accept high speed and feed.

The tool is to be used number of times by sharpening.

High Speed Steel (HSS)

The basic composition of HSS is 18% W, 4% Cr, 1% V, 0.7% C and rest Fe. Such HSS tool could machine (turn) mild steel jobs at speed only upto 20 ~ 30 m/min (sometime 60 m/min). It is used as cutting tool material where;

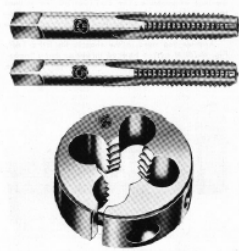
- the tool geometry and mechanics of chip formation are complex, such as helical twist drills, reamers, gear shaping cutters, hobs, form tools, broaches etc.
- brittle tools like carbides, ceramics etc. are not suitable under shock loading

High Speed Steel (HSS)

With time the effectiveness and efficiency of HSS (tools) and their application range were gradually enhanced by improving its properties and surface condition through -

- • Refinement of microstructure
- • Addition of large amount of cobalt and Vanadium to increase hot hardness and wear resistance respectively

- Manufacture by powder metallurgical process
- Surface coating with heat and wear resistive materials like TiC, TiN, etc by Chemical Vapour Deposition (CVD) or Physical Vapour Deposition (PVD)



Addition of large amount of Co and V, refinement of microstructure and coating increased strength and wear resistance and thus enhanced productivity and life of the HSS tools remarkably. The cost of coated tool is 2 to 5 times the cost of plain HSS tool. But life is 5 to 10 times that of plain HSS tool. It can be used as insert, which is clamped or brazed or welded to a carbon or low alloy steel body.

Type	C	W	Mo	Cr	V	Co	R _c
T-1	0.7	18		4	1		
T-4	0.75	18		4	1	5	
T-6	0.8	20		4	2	12	
M-2	0.8	6	5	4	2		64.7
M-4	1.3	6	5	4	4		
M-15	1.55	6	3	5	5	5	
M-42	1.08	1.5	9.5	4	1.1	8	62.4

Stellite

- This is a cast alloy of Co (40 to 50%), Cr (27 to 32%), W (14 to 19%) and C (2%). Stellite is quite tough and more heat and wear resistive than the basic HSS (18 – 4 – 1). But such stellite as cutting tool material became obsolete for its poor grindability and specially after the arrival of cemented carbides. It retains hardness up to 750 degree C and has low coefficient of friction. Since it is castable, it is specially useful for making form tools.

Cemented Carbides

- **Straight or single carbide**

First the straight or single carbide tools or inserts were powder metallurgically produced by mixing, compacting and sintering 90 to 95% WC powder with cobalt. The hot, hard and wear resistant WC grains are held by the binder Co which provides the necessary strength and toughness. Such tools are suitable for machining grey cast iron, brass, bronze etc. which produce short discontinuous chips and at cutting velocities two to three times of that possible for HSS tools.

Cemented Carbides

- **Composite carbides**

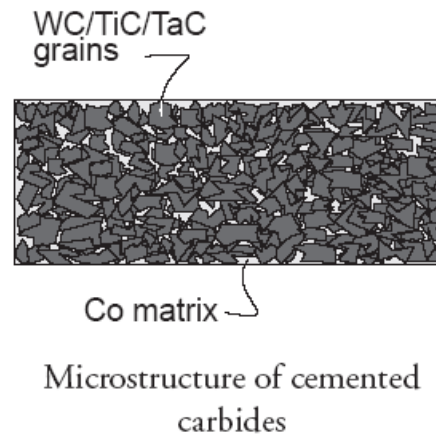
- The single carbide is not suitable for machining steels because of rapid growth of wear, particularly crater wear, by diffusion of Co and carbon from the tool to the chip under the high stress and temperature bulk (plastic) contact between the continuous chip and the tool surfaces.
- For machining steels successfully, another type called composite carbide have been developed by adding (8 to 20%) a gamma phase to WC and Co mix. The gamma phase is a mix of TiC, TiN, TaC, NiC etc. which are more diffusion resistant than WC due to their more stability and less wettability by steel.

Cemented Carbides

- **Mixed carbides**

- Titanium carbide (TiC) is not only more stable but also much harder than WC. So for machining ferritic steels causing intensive diffusion and adhesion wear a large quantity (5 to 25%) of TiC is added with WC and Co to produce another grade called Mixed carbide. But increase in TiC content reduces the toughness of the tools. Therefore, for finishing with light cut but high speed, the harder grades containing upto 25% TiC are used and for heavy roughing work at lower speeds lesser amount (5 to 10%) of TiC is suitable.

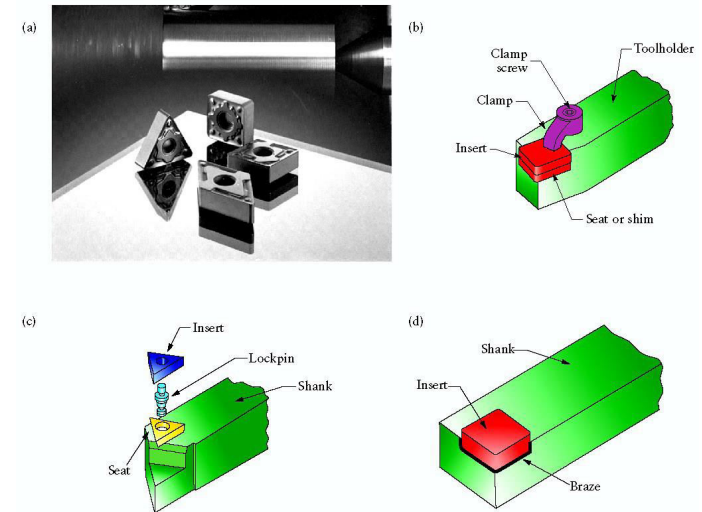
Cemented Carbides



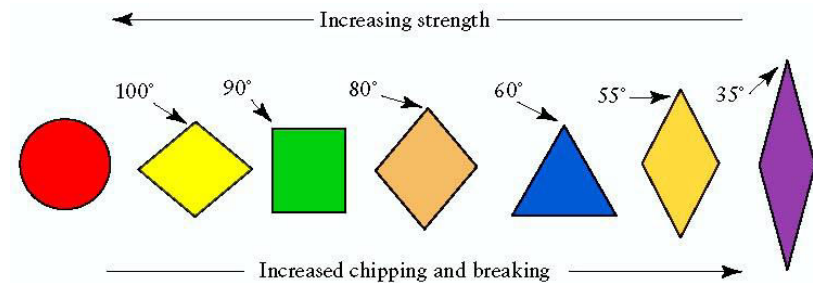
Cemented Carbides Tips and Inserts



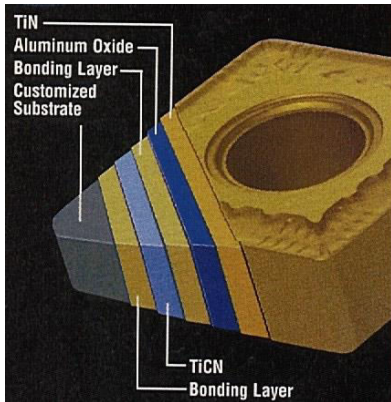
Cemented Carbides Tips and Inserts



Range of materials	Typical Machining Operations	Demands on the grade
P Steel, cast steel, stainless steel, long chipping malleable iron.	01 05 10 15	Extreme finishing to high surface finish.
	20 25	Finishing at high cutting speed.
	30 35	Copy turning operations.
	40 45	Rough turning and turning with low cutting speeds.
	50	Heavy roughing and intermittent machining.
		High wear resistance. ↑ Good toughness and edge strength.
M Steel, cast steel, manganese steel, alloy cast iron, austenitic stainless steel castings, malleable iron, free-cutting steel.	10	Finishing at high cutting data
	20	Finishing at low cutting data
	30	
	40	Heavy roughing and intermittent machining.
		High wear resistance. ↑ Good toughness and edge strength.
K Cast iron, chilled cast iron, short chipping malleable iron, hardened steel, non-ferrous metals, plastics, wood.	01 05	Finishing to high surface finish.
	10 15	Semi-finishing to light roughing.
	20 25	Heavy roughing and intermittent machining.
	30	Machining at low cutting data.
		High wear resistance. ↑ Good toughness and edge strength.



Coated Carbide



- One advance in cutting tool materials involves the application of a very thin coating ($\sim 10 \mu\text{m}$) to a
- K-grade substrate, which is the toughest of all carbide grades. Coating may consist of one or more
- thin layers of wear-resistant material, such as *titanium carbide* (TiC), *titanium nitride* (TiN), *aluminum oxide* (Al_2O_3), and/or other, more advanced materials. Coating allows to increase significantly the cutting
- speed for the same tool life.

Oxide Tools (Ceramics)

Ceramic cutting tools are harder and more heat-resistant than carbides, but more brittle. They are well suited for machining cast iron, hard steels, and the super alloys.

Two types of ceramic cutting tools are available: the alumina-based and the silicon nitride-based ceramics.

The alumina-based ceramics are used for high speed semi- and final-finishing of ferrous and some non-ferrous materials.

The silicon nitride-based ceramics are generally used for rougher and heavier machining of cast iron and the super alloys.

Ceramic Tools

Cutting tool properties of alumina ceramics.

Advantages

- very high hardness
- very high hot hardness
- chemical stability
- anti welding
- less diffusivity
- high abrasion resistance
- high melting point
- very low thermal conductivity
- very low thermal expansion coefficient

Shortcoming

- poor toughness
- poor tensile strength
- poor TRS
- low thermal conductivity
- less density

Ceramic Tools

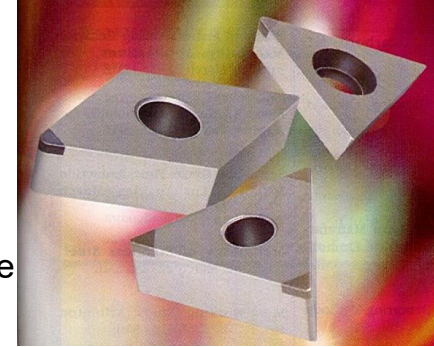
- Basically three types of ceramic tool bits are available in the market;
 - • Plain alumina with traces of additives – these white or pink sintered inserts are cold pressed and are used mainly for machining cast iron and similar materials at speeds 200 to 250 m/min
 - • Alumina; with or without additives – hot pressed, black colour, hard and strong – used for machining steels and cast iron at $VC = 150$ to 250 m/min
 - • Carbide ceramic or Cermets ($\text{Al}_2\text{O}_3 + 30\% \text{ TiC}$) cold or hot pressed, black colour, quite strong and enough tough – used for machining hard cast irons and plain and alloy steels at 150 to 200 m/min.
- All above materials have very high wear resistance but low toughness, therefore they are suitable only for continuous operations such as finishing turning of cast iron and steel at very high speeds. There is no occurrence of built-up edge, and coolants are not required.

Diamond Tools

- **Diamond:** They are of two types - industrial grade natural diamonds, and synthetic polycrystalline diamonds. Because diamonds are pure carbon, they have an affinity for the carbon of ferrous metals. Therefore, they can only be used on non-ferrous metals. Feeds should be very light and high speeds. Rigidity in the machine tool and the setup is very critical because of the extreme hardness and brittleness of diamond.

Cubic Boron Nitride (CBN)

- Next to diamond, CBN is the hardest tool material. CBN is used mainly as coating material because it is very brittle. CBN is suitable for cutting ferrous materials.



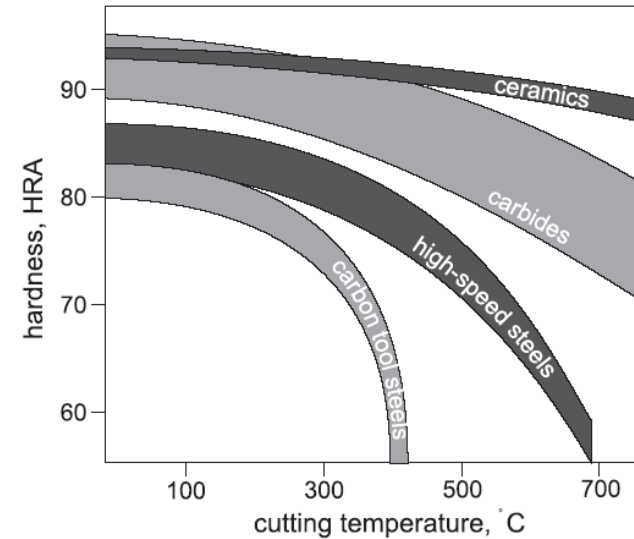
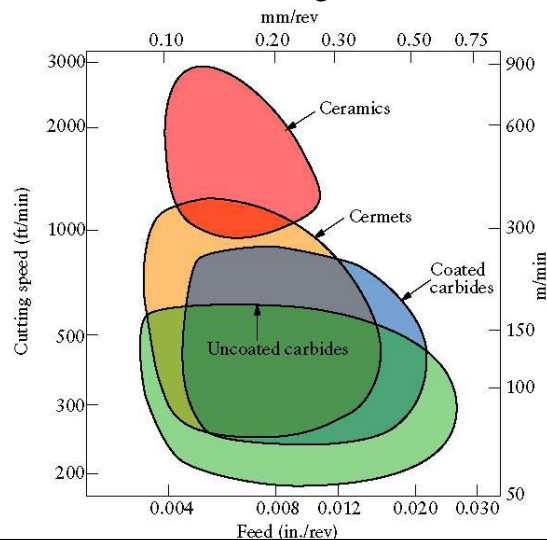
KYON

- It is a ceramic tool with alumina base and reinforced by silicon carbide whiskers.
- Tough and wear resistant structure.
- Suitable for intermittent cutting and machining of Nickel based alloys.
- Superior to coated carbides.
- Resistant to chipping.
- Cutting speed 3 to 3 times that of plain carbide tools.

Si-Al-O-N

- It is produced by milling together Silicon nitride, Aluminium nitride, Alumina and Yttria, and dried, pressed to shape and sintered at 1800 degree C.
- Tougher than alumina.
- Suitable for interrupted cuts.
- Cutting speed 3 to 3 times that of plain carbide tools.

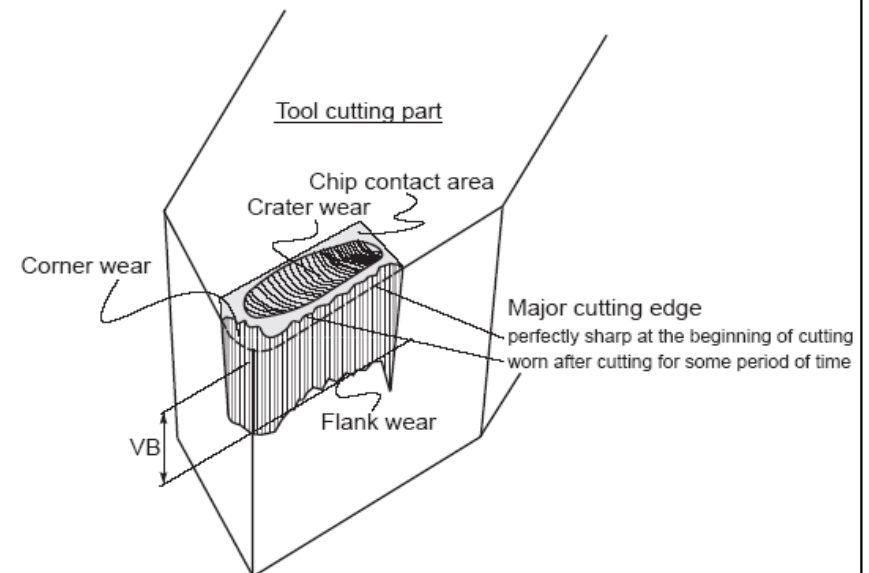
Cutting tool material and recommended speed range



Hot hardness for different tool materials

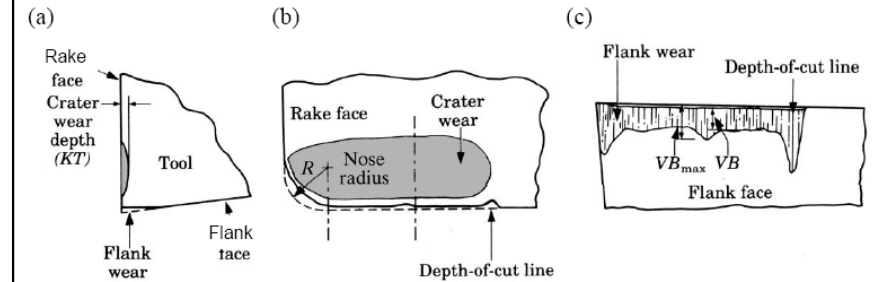
Tool Wear

- Loss of materials due to rubbing of two sliding surfaces accompanying friction is called wear. In case of machining loss of cutting tool material is called tool wear. The cutting tool is subjected to (a) high localised stresses (b) high temperature (c) sliding of chip along the rake face (d) rubbing of flank surface with freshly machined workpiece surface and (e) vibration & shock due to improper machining. Due to above factors the loss of material from the tool body accelerates and it loses sharp cutting edge which further hinders effective and efficient machining.



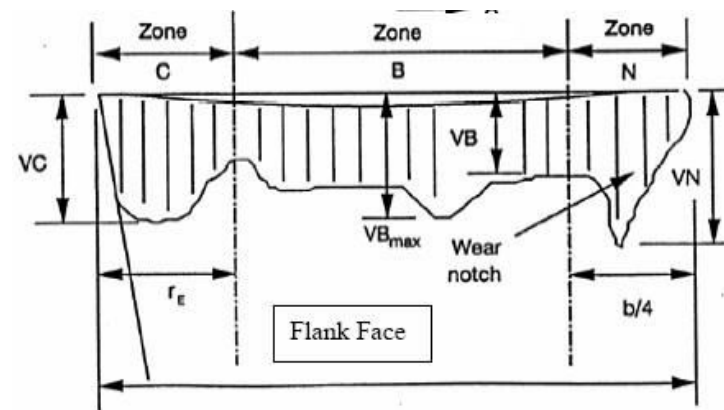
Types of Tool Wear

1. Flank wear
2. Crater wear
3. Nose or corner wear
4. Chipping of cutting edge



Flank Wear

- Flank Wear:** This wear appears as wear land of non-uniform width on side and end flank surfaces of the cutting tool. The reasons for this wear can be attributed to (a) rubbing of the tool flank along the freshly machined workpiece surface (b) high temperature which affects tool material properties as well as the work piece surface. The wear land is larger near the two ends of the active portion of the principal cutting edge. The width of wear land is usually maximum at rear end which ultimately results in groove or notch. At the nose chip flow is complicated and the wearing conditions severe. ISO has recommended the maximum width of wear land for different tool materials both for roughing and finishing operation.



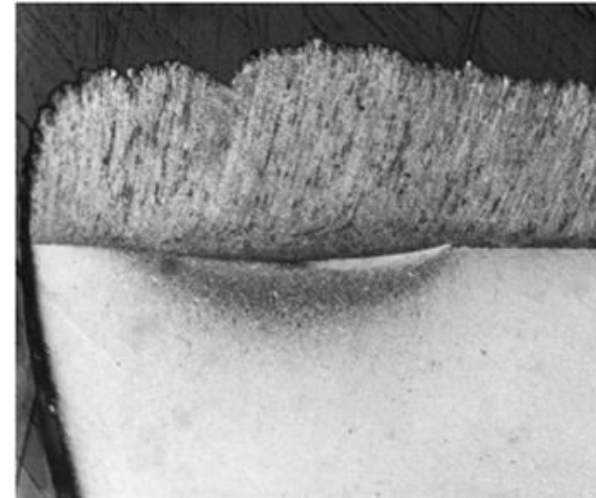
$$VB = 0.3 \text{ mm and } VB_{\text{Max.}} = 0.6 \text{ mm}$$

Cutting forces increase significantly with flank wear. If the amount of flank wear exceeds some critical value, ($V_B > 0.5\text{-}0.6 \text{ mm}$), the excessive cutting force may cause tool failure.

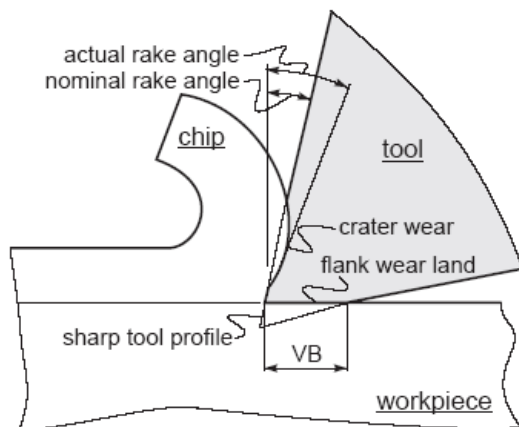
Crater Wear

- It appears as a pit or crater on the rake surface of the cutting tool near the principal cutting edge. The most significant factors influencing the formation of crater wear are (a) temperature at the tool-chip interface (b) the chemical affinity between the tool and workpiece materials (c) rubbing between chip and tool rake face accompanying friction. Crater wear affects the mechanics of the process increasing the actual rake angle of the cutting tool and consequently, making cutting easier. At the same time, the crater wear weakens the tool wedge and increases the possibility for tool breakage. In general, crater wear is of a relatively small concern. ISO recommends the following value of crater depth as the tool failure criterion.

Crater Wear



Crater Wear



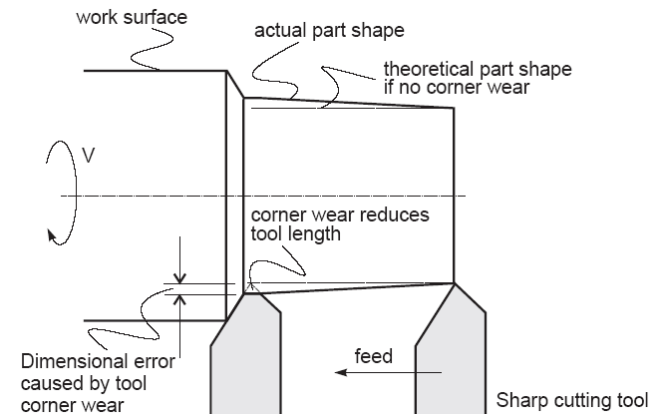
Crater Wear

- $KT = 0.06 + 0.3f$; where f = feed per revolution
- $KT / KM = 0.2$ to 0.4 (Opitz and Weber)
- Location of the maximum depth of crater coincides with the location of the maximum temperature at the chip –tool interface.

Nose or Corner Wear

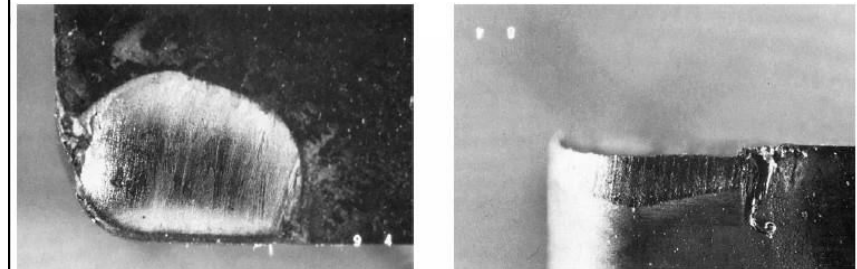
- It occurs on the tool corner which may be considered as a part of the wear land since there is no distinguished boundary between the corner wear and flank wear land. We consider corner wear as a separate wear type because of its importance for the precision of machining. Corner wear actually shortens the cutting tool thus increasing gradually the dimension of machined surface and introducing a significant dimensional error in machining, which can reach values of about 0.03 to 0.05 mm.

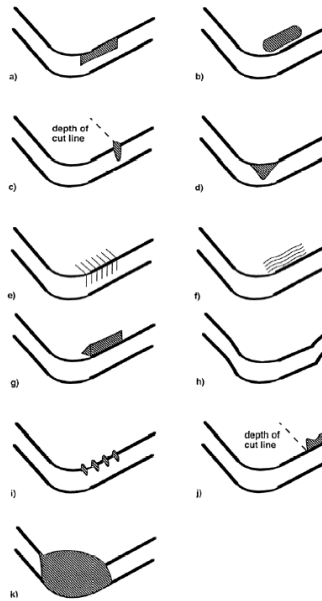
Nose or Corner Wear



Chipping of the cutting edge

- Chipping is the term used to describe the breaking away of a small piece from the cutting edge of the tool. The chipped tool material may be very small or relatively large in size. Unlike above mentioned wears, chipping results in sudden loss of tool material and change in tool geometry which affects machining performance. The reasons for chipping can be attributed to (a) mechanical shock (impact due to interrupted cutting like milling), (b) thermal fatigue (cyclic variation in temperature of the tool), (c) transient thermal stresses, (d) excessive plastic deformation of the cutting edge, (e) localised cooling, (f) vibration and chatter, (g) excessive crater and flank wears.





Mechanisms of wear

- **Shearing at high temperature:** The strength of tool material decreases at high temperature which is encountered during machining. Due to work hardening the chip becomes harder and is sufficiently hardened to exert frictional stress sufficient to cause yielding by shear of the hard tool material.

Mechanisms of wear

- **Abrasion:** Loss of material from rake and flank surfaces of cutting tool may occur due to abrading action of hard particles formed during machining. The workpiece and the chip may contain hard particles like inclusions, sand particles etc. which act as small cutting edges like those of a grinding wheel on the surface of cutting tool. Also fragments of built up edge which are very hard, stick to the underside of the chip and plough the rake surface producing grooves. This action is relatively more severe on the flank surface because of nature of contact and the hard backing provided by the workpiece as compared to the ribbon like chip on the rake surface.

Mechanisms of wear

- **Adhesion:** During machining the freshly cut chip at very high temperature and pressure gets welded to the high spots on the rake surface. The strength of the bonding at the points of adhesion is often so great that while attempting to free the surfaces, separation takes place not along the interface but either in chip or tool material.

Mechanisms of wear

- **Diffusion:** With progressive increase in cutting speed the temperature produced at the tool chip interface becomes higher. At this condition the alloying atoms from the hard tool surface may diffuse into softer material of the chip due to concentration gradient. Similarly certain atoms from the chip may also diffuse into the surface layer of the tool, thus weakening it. The particles from this layer can be easily dislodged or sheared off during further machining. Diffusion phenomenon is strongly dependent on temperature. This wear will take place both at flank and rake surfaces and depending on the magnitude and nature of temperature distribution, the predominant wear may shift to crater zone.

Mechanisms of wear

- **Fatigue:** During sliding of chip over the rake surface of the tool the asperities on both surfaces get interlocked under high pressure. Due to friction compressive stress is developed on one side of the asperities while tensile stress is induced on the other side. After the asperities of a given pair have moved over, the above stresses are relieved. New pairs of asperities are continuously formed and the stress cycle is repeated. This phenomenon causes surface cracks and the rake surface ultimately loses material in the form wear debris. The other factors that contribute to loss of material in this mode are variable thermal stresses owing to temperature variation brought about by cutting fluid, discontinuous chip formation, variable dimensions of cut etc.

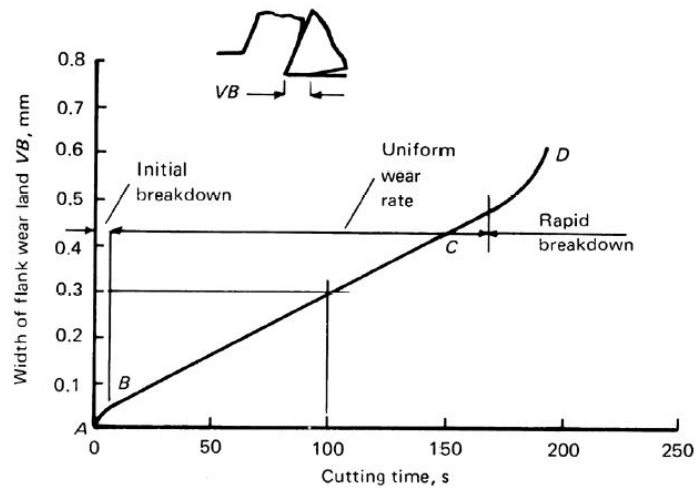
Mechanisms of wear

- **Electrochemical effect:** Since very high temperature is produced at the tool chip interface therefore thermo-electric emf may be produced between hot and cold junctions which aids traditional wear on the rake surface. For example the current produced due to thermo-electric emf may increase the diffusion of carbon ions from the carbide tools to the flowing chip (galvanic corrosion).

Mechanisms of wear

- **Oxidation effect:** The freshly cut chips and the machined surfaces may react with atmospheric oxygen to form hard oxides which in turn may damage both rake and flank surfaces of the cutting tool.
- **Chemical decomposition:** Some localised chemical reactions may occur that weaken the tool material through formation of weak compounds or dissolution of the bond between materials of the tool. If the cutting fluid used in machining is active to the tool material then wear may be greatly accelerated.

Growth of wear



In the beginning, the tool is sharp and the wear land on the flank surface has zero width. With further machining the wear land develops and grows in size on account of abrasive wear, shear etc. The magnitude of temperature at the interfaces may cause a shift from abrasion to adhesion or from adhesion to diffusion wear process. In the above figure AB represents initial formation of wear land while BC shows steady growth of wear land due to abrasion. The portion CD represents rapid growth of wear land due to onset of diffusion process. If a cutting tool is operated in this zone for a longer period of time then catastrophic tool failure may occur.

Cutting Fluids

Use of Cutting Fluids provides following benefits

- Reduction of cutting forces and energy consumption.
- Increase in tool life.
- Improved surface finish and accuracy of size.
- Easy removal of chips.

Cutting Fluids

- Less distortion of work piece due to cooling effect.
- Corrosion prevention on work piece.
- Lubrication of machine tool slide ways.

Cutting Fluids

Use of Cutting Fluid should be justified on economic basis.



Cutting Fluids

- Use of cutting fluid may produce toxic vapours which may be dangerous to human health.
- Microbial contamination, cancer causing additives, skin irritants, unpleasant odour, etc.
- May damage the work surface by chemical reaction. Fire hazards, may decompose and damage the circulation systems.

Types of Cutting Fluids

- Straight or Neat Oils: Mineral oils, Fatty oils, and combination of fatty and mineral oils. These are used undiluted and mixed with high pressure compounds based on chlorine, sulfur and phosphorous.

Good lubricating properties but poor heat transfer characteristics.

Used for low cutting speed applications.

Types of Cutting Fluids

- Soluble Oils: These consists of oil with emulsifiers that allow the oil to disperse in water. Concentration-3 to 30 %.
- Widely used in industry and least expensive.
- Better heat removal capacity.

Types of Cutting Fluids

- Synthetic Fluids : These are oil-free solutions formulated from alkaline inorganic and organic compounds, usually with the addition of corrosion inhibitors. They are diluted with water. Concentration 3 to 10 %.
- Better cooling performance.

Types of Cutting Fluids

- Semi-synthetic Fluids: These are combination of synthetic and soluble oils and exhibit characteristics of both type.
- Good corrosion resistance, lubrication and tolerance to contamination.

Composition of Cutting Fluids

The cutting fluid may contain the following

- Base oil
- Emulsifier
- Corrosion or rust inhibitors
- Lubricating, anti-wear and extreme pressure additives
- Neutralizing agents
- Fungicides
- Foam inhibitors
- Stabilizing agents

Application of Cutting Fluids

- Manual Application
- Flood Application
- Jet Application
- Mist Application
- Through the Tool Application

Manual Application

- Cutting fluids and lubricants are often applied manually for small batch and job shop production. Application with a brush by the operator is the easiest and least expensive method of fluid delivery.
- Disadvantages : intermittent fluid application, poor chip removal, limited access of fluid to the cutting zone.

Flood Application

- Flood the tool, workpiece, and cutting zone with fluid delivered from a low pressure nozzle directed appropriately.
- Continuous flow, better chip removal.
- Cutting fluid drains into the sump, filtered and again supplied through nozzle.
- Careful orientation of nozzle ensures cutting fluid is not deflected away from the cutting zone by rotating tool or workpiece.

Jet Application

- A high pressure and high velocity jet of fluid is directed at the cutting zone.
- Very effective in removing chips from cutting area.
- Suitable for high cutting speed applications.

Mist Application

- Nozzle produces fine droplets of cutting fluid. Drop size varies from 5 to 25 micrometers.
- Mist is directed at the cutting zone at high velocity.
- Absorbs more heat than flooding application.
- Suitable for high speed cutting applications.
- When uncut chip thickness is small in machining.
- Can reach inaccessible area.
- Better conservation of cutting fluid
- Disadvantage: health risk

Through the Tool Application

- Supply of fluid through the tool shank.
- Application: drilling, grinding
- Better tool life and better chip removal.

Effects of cutting Fluids

Effects of workpiece materials

- Environmental attack particularly with sulphur and chlorine additives.
- Machined components should be cleaned and washed thoroughly.
- Use low viscosity water based fluid for ease of cleaning and filtering.

Effects of cutting Fluids

Effect on Machine-tool

- Must be compatible with machine tool and its component materials.
- Compatible with lubricants used in machine tools.

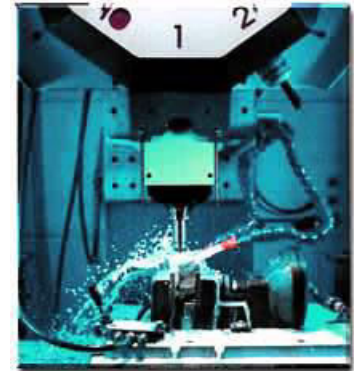
Effects of cutting Fluids

Biological and Environmental Effects

- Health risk due to fumes , smoke and odours.
- Air and water contaminations.
- Chemical changes over time.
- Growth of microbes in the presence of water.

Effects of cutting Fluids

Clarification, Recycling and disposal.



Tool Life

- The length of time for which the cutting tool can be usefully engaged till regrind or replacement is called Tool Life.
- The amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed.
- A tool that no longer performs its intended function is said to have 'failed' and hence reached the end of its useful life.

Failure of Tool

Direct Criteria

- Limiting value of Flank Wear
- Limiting value of Crater Wear
- Chipping of cutting edge
- Crack formation on cutting edge

Failure of Tool

Indirect Criteria

- Limiting Value of Surface Roughness
- Limiting Value of change in machined dimension
- Limiting Value of increase in cutting forces
- Limiting Value of volume of metal removed
- Preliminary failure
- Complete failure

Tool Life

- Tool life is defined in two ways :
 - (a) **In R & D** : Actual machining time (period) by which a fresh cutting tool (or point) satisfactorily works after which it needs replacement or reconditioning. The modern tools hardly fail prematurely or abruptly by mechanical breakage or rapid plastic deformation. Those fail mostly by wearing process which systematically grows slowly with machining time. In that case, **tool life means the span of actual machining time by which a fresh tool can work before attaining the specified limit of tool wear.** Mostly tool life is decided by the machining time till flank wear, VB reaches 0.3 mm or crater wear, KT reaches 0.15 mm.

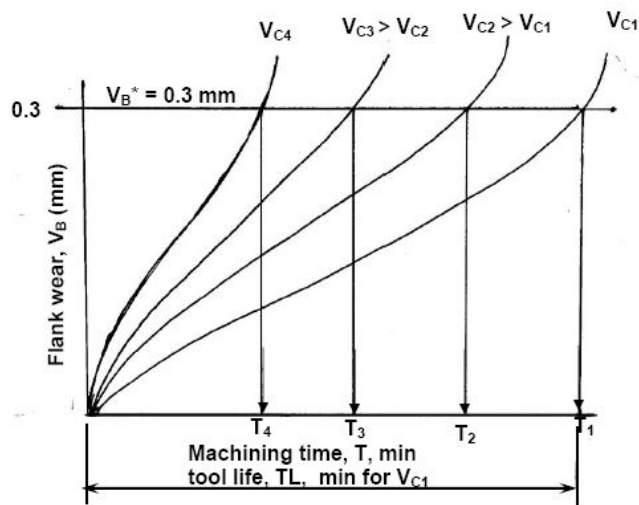
Tool Life

- (b) **In industries or shop floor** : The length of time of satisfactory service or amount of acceptable output provided by a fresh tool prior to it is required to replace or recondition.

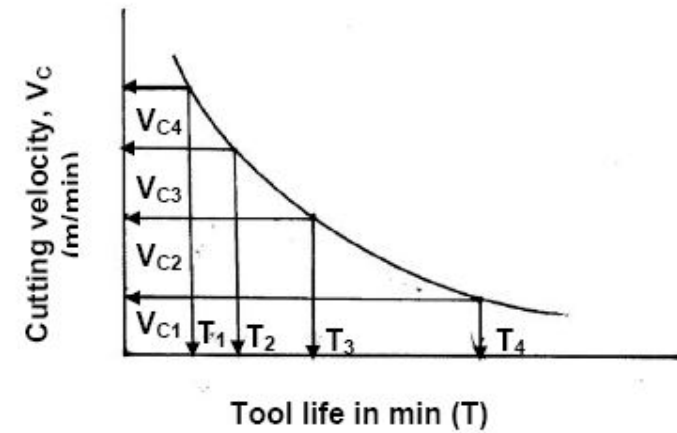
Taylor's Tool Life

- Wear and hence tool life of any tool for any work material is governed mainly by the level of the machining parameters i.e., cutting velocity, feed, and depth of cut. Cutting velocity affects maximum and depth of cut minimum.

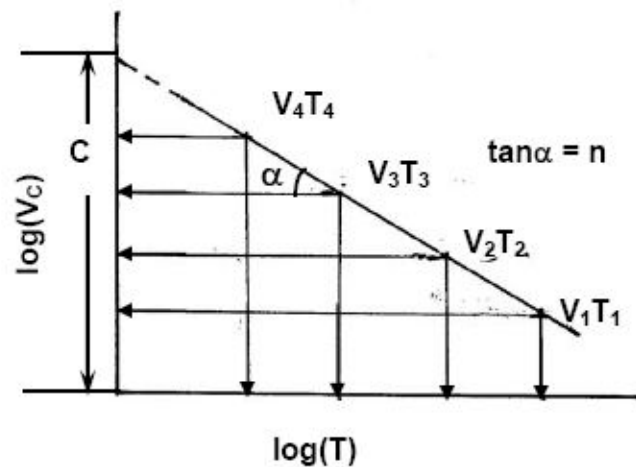
Taylor's Tool Life



Taylor's Tool Life



Taylor's Tool Life



Taylor's Tool Life Equation

$$VT^n = C \quad \text{or} \quad T = \frac{C^{\frac{1}{n}}}{V^{\frac{1}{n}}} = \frac{C_1^{\frac{1}{n}}}{V^{\frac{1}{n}}}$$

Value of Tool Life Exponent, n

HSS-	0.15 to .20
Cemented Carbide-	0.30 to .49
Ceramic-	0.50 to 0.70

Taylor's Extended Tool Life Equation

$$T_{(Time)} = \frac{K}{V^{1/n} f^{1/n_1} d^{1/n_2}} \quad \begin{cases} n_2 > n_1 > n > 0 \\ 0 < n < 1 \\ K > 0 \end{cases}$$

Effect of Variables on Tool Life

Tool material properties

- High Hot Hardness
- Toughness
- Wear resistance
- Lack of chemical affinity with work material
- High thermal conductivity and specific heat
- Low coefficient of thermal expansion

Effect of Variables on Tool Life

Coating of tool

- HSS tool coated with TiN
- Tungsten Carbide tool coated with TiC, Aluminium Oxides, TiN etc.

Effect of Variables on Tool Life

Work piece material

- Low strength and hardness to reduce cutting forces, temperature and abrasive wear
- Absence of abrasive constituents like scale, sand and slag inclusions
- Presence of desirable additives like lead and sulfur
- Lack of work hardening tendency
- Favourable microstructure

Effect of Variables on Tool Life

Speed, Feed and Depth of Cut

Wear increases with increase in speed, feed and depth of cut.

Effect of Variables on Tool Life

Tool Geometry

- Rake Angle
- Relief Angle
- Side Cutting Edge Angle
- Nose Radius

Effect of Variables on Tool Life

- Cutting Fluid
For HSS and carbon steel cutting fluid increases tool life.
For Carbides and Ceramics it has negligible effect.

Effect of Variables on Tool Life

- Vibration behaviour of Machine -Tool -Work system
- Interruption in the Cut
- Built-up edge

Numerical Problems

- A mild steel bar is turned with HSS tool. Determine the tool life for a cutting velocity of 40 m/min, if the tool life equation is $VT^{0.2} = 80$. Also determine the cutting speed for 60 min tool life.
- Mild steel bars of 50 mm diameter are to be turned over a length of 160 mm with a depth of cut of 1.5 mm, feed of 0.2 mm/rev. at 230 rpm by HSS tools. If the tool life equation is given by $V T^{0.2} f^{0.3} d^{0.12} = 50$, determine how many components may be turned before regrinding of the tool.

Machinability

Objective of Machining

It is obviously attempted to accomplish machining effectively, efficiently and economically as far as possible by removing the excess material smoothly and speedily with lower power consumption, tool wear and surface deterioration. But this may not be always and equally possible for all the work materials and under all the conditions.

Machinability

- The machining characteristics of the work materials widely vary and also largely depend on the conditions of machining. A term; 'Machinability' has been introduced for gradation of work materials w.r.t. machining characteristics

Machinability

Definition:

- It is generally applied to the machining properties of work material
- It refers to material (work) response to machining
- It is the ability of the work material to be machined
- It indicates how easily and fast a material can be machined.

Machinability

- For instance, saying ‘material A is more machinable than material B’ may mean that compared to ‘B’,
 - ‘A’ causes lesser tool wear or longer tool life
 - ‘A’ requires lesser cutting forces and power
 - ‘A’ provides better surface finish

Machinability

General definition:

It is related to the machining characteristics of any work-piece material that govern the ease or difficulty with which it can be machined under a given set of cutting conditions.

Machinability

Attempts were made to measure or quantify machinability and it was done mostly in terms of :

- tool life which substantially influences productivity and economy in machining
- magnitude of cutting forces which affects power consumption and dimensional accuracy
- surface finish which plays role on performance and service life of the product.

Often cutting temperature and chip form are also considered for assessing machinability.

Machinability Index

Machinability rating

$$= \frac{\text{speed (fpm) of machining the work giving 60 min tool life}}{\text{speed (fpm) of machining the standard metal giving 60 min tool life}} \times 100$$

Factors affecting Machinability Index

Machine Variables

- Capacity of Machine (power, torque, and accuracy of machine)
- Rigidity of machine and work holding devices

Factors affecting Machinability Index

Tool Variables

- Tool materials
- Tool geometry
- Nature of engagement of tool with workpiece

Factors affecting Machinability Index

Cutting conditions

- Cutting speed
- Feed
- Depth of cut
- Cutting fluid

Factors affecting Machinability Index

Work Material

- Hardness
- Tensile strength
- Chemical composition
- Microstructure
- Degree of cold worked
- Shape and dimensions of work-piece
- Rigidity of work-piece
- Strain hardenability

Possible Ways Of Improving Machinability Of Work Piece

The machinability of the work materials can be more or less improved, without sacrificing productivity, by the following ways :

- Favourable change in composition, microstructure and mechanical properties by mixing suitable type and amount of additive(s) in the work material and appropriate heat treatment
- Proper selection and use of cutting tool material and geometry depending upon the work material and the significant machinability criteria under consideration
- Optimum selection of VC and so based on the tool – work materials and the primary objectives.

Possible Ways Of Improving Machinability Of Work Piece

- Proper selection and appropriate method of application of cutting fluid depending upon the tool – work materials, desired levels of productivity i.e., VC and so and also on the primary objectives of the machining work undertaken
- Proper selection and application of special techniques like dynamic machining, hot machining, cryogenic machining etc, if feasible, economically viable and eco-friendly.